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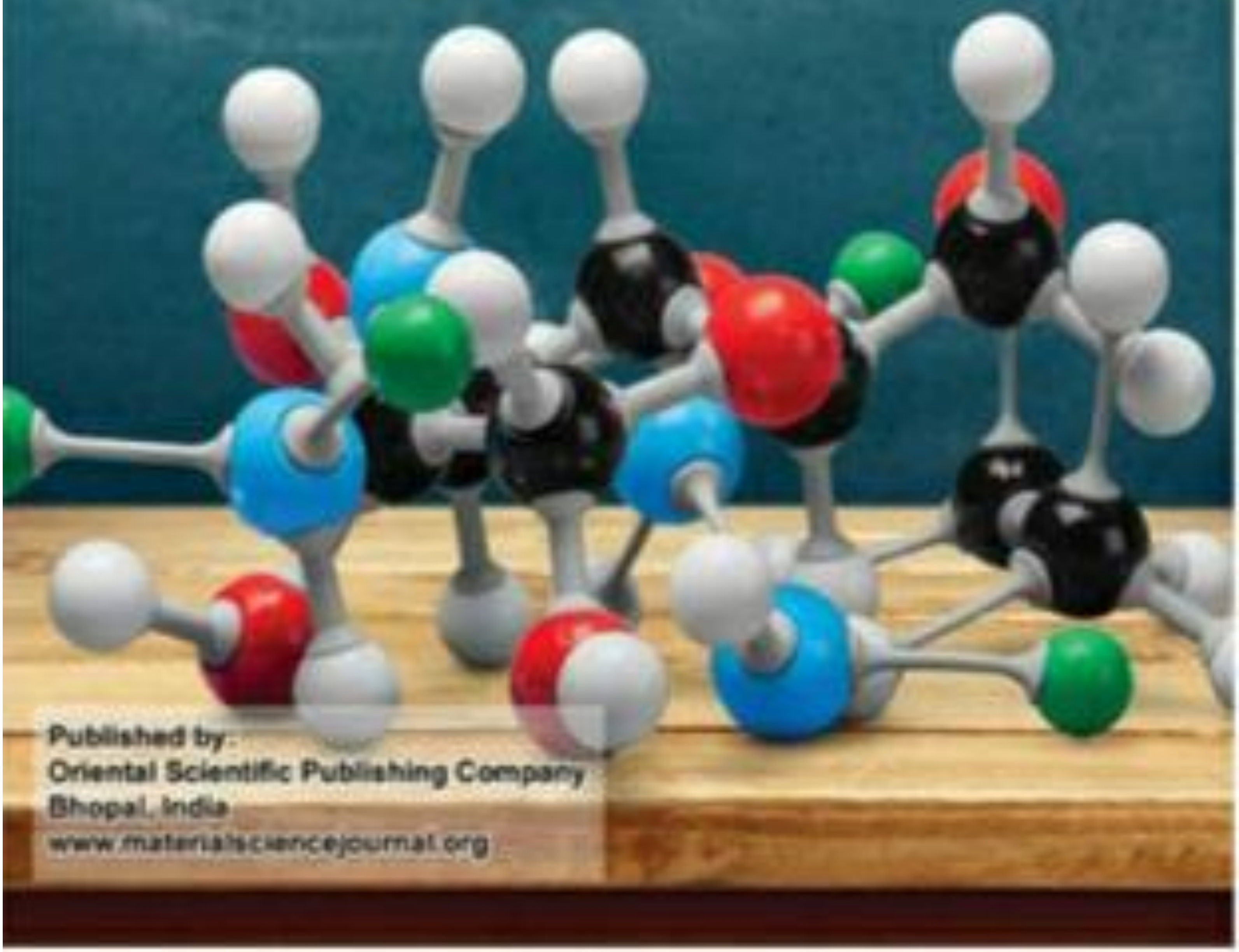

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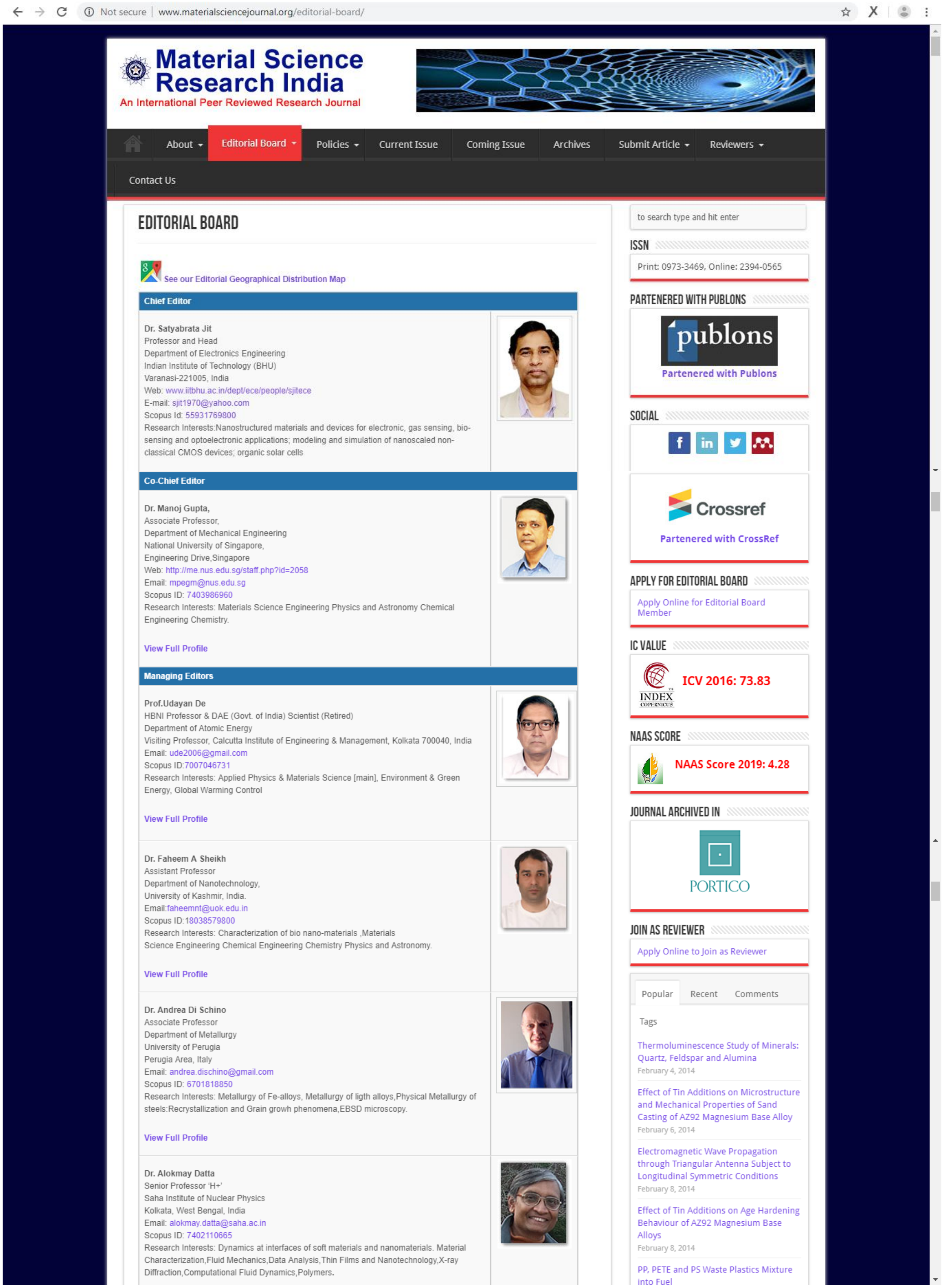

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Tensile, Thermal and Moisture Absorption Properties of Polyvinyl Alcohol (PVA) / Bengkuang (*Pachyrhizus erosus*) Starch Blend Films

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Abstract

This paper described of the tensile, thermal, and moisture absorption characteristic of polyvinyl alcohol (PVA) / bengkuang (*Pachyrhizus erosus*) starch blend films. The film was produced through solution casting method. Tensile, thermogravimetric analysis and moisture test were studied to determine the tensile strength, thermal stability, and moisture absorption, respectively. The highest tensile strength (TS) was 15.86 ± 0.69 MPa for pure PVA film. This result was higher than bengkuang starch and its blends film. Tensile elongation (TE) decreased as increased bengkuang starch content in PVA. The thermal degradation of PVA film was higher 10 °C than bengkuang starch films in range temperature 200-380 °C. The addition of bengkuang starch in PVA also increased moisture absorption. The highest moisture absorption was in bengkuang starch film. This blend film's tensile, thermal, and moisture properties probably suggested it could be suitable for food packaging.

Article History

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Bengkuang Starch;
Moisture Absorption;
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Tensile Strength;
Thermal Stability.

Introduction

Using synthetic plastics has increased significantly from last several years due to its a serious impact on environment especially plastic waste pollution.[1-3] Generally, synthetic plastic has disadvantage such as undegradable in environment, expensive, and limitation of using due to it made from oil.[4] To reduce the use of synthetic plastic, polyvinyl alcohol (PVA) is one of candidate to substitute the one.[5]

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PVA is environmental polymer which able to dissolved by high temperature in water. It has good biocompatibility and good resistance to chemicals. The high crystalline structure made it become superior mechanical properties.[5-6] However, PVA also having weakness as it expensive and longtime degradable to environment. To overcome this weakness, mixing with starch become one of solution to push the cost production.

Starch is composed of two monomers (D-glucose) which usually consists of amylose and amylopectin. Amylose is a linear chain with α- ($1 \rightarrow 4$) glucose units. The degree of polymerization between 500-6000 units of glucose depending on the source. Whereas, amylopectin is a branched chain of α- ($1 \rightarrow 4$) glucose units and added by next chains to α- ($1 \rightarrow 6$) glucose units.[7] The ratio between amylose and amylopectin is important to define its properties. The highest amylose in starch made it good mechanical properties.[8] One starch candidate that has high amylose content is bengkuang starch.[3,9]

The amylose content of bengkuang starch is varied depend on their place of growth, species plant, climate, and fertilization as reported by previous report [9]. Mali et al (2005) had studied about bengkuang starch from Brazil. They reported that bengkuang starch from Brazil has 30-40% of amylose content, a homogeneous structure, and rigid. The several research about bengkuang starch have been explored. Previous researcher reported about mechanical and thermal properties of bengkuang starch film. They reported that the tensile strength of bengkuang starch film was 6-7 MPa without glycerol.[8]

Mixing PVA and starch become special concern for researchers in the field of food packaging. This way was effective to reduce the cost of PVA film production. Besides that, the presence of starch made it no longer time for degradable in environment. Therefore, this study investigated the mixture of PVA and bengkuang starch blend films. According to the best our knowledge, there is no publication about the mixing of these two materials. The film was characterized by tensile test, thermogravimetric analysis, and moisture absorption rate.

Materials and Methods

Materials

Polyvinyl Alcohol (PVA) technical grade (full hydrolysis) was purchased from PT. Prima Global Chemical, Indonesia. The compatibilizer substance was Natriumtetraborat-10-Hydrat (*pro analyst*) under Merck product from the Faculty of Agriculture, Andalas University. It was used for coupling agent between PVA and starch. Glycerol as plasticizer (analyst type: purity 99%) was purchased from PT. Bratachem, Padang, Indonesia. Other chemical reagents were available at the Metallurgy Mechanical Laboratory, Andalas University. Bengkuang starch was obtained from extraction process of bengkuang tuber obtained in Padang, West Sumatra (amylose 43%). The extraction method of bengkuang starch was explained in the next section.

Extraction of Bengkuang Starch

Bengkuang was chosen as the object of research due to its potential properties such as high amylose content (43%), abundant, and low cost. The amylose content influences the mechanical properties of starch film. First, bengkuang tuber was prepared and peeled into small pieces. It was crushed using ice blender at 10000 rpm and 5 min for obtaining porridge. It was filtered using screen printing (200 mesh) to separate bagasse and suspension. The suspension was precipitated for 5 h to obtain the bengkuang starch. It was dried in drying oven at 50 °C for 20 h. Bengkuang starch was collected and crushed to become dry starch powder.

Film Fabrication

The composition of PVA and bengkuang starch can be seen in Table 1. PVA / bengkuang starch film was made by solution casting method. PVA pellet was dispersed into a 100 ml distilled water. It was heated and stirred using hot plate stirrer at 90 °C and 500 rpm for 60 min until completely dissolved. 0.1 gram of sodium-tetraborate-10-hydrate, 1 ml of glycerol, and bengkuang starch were added to PVA solution, then heated 90 °C for 30 min. The mixture was casted in petri dish (diameter 15 cm) and dried in drying oven at 50 °C for 20 h.

Tensile Properties

The tensile test was conducted to know the mechanical properties of PVA, starch, and its blend films. Tensile strength and elongation at break were obtained from tensile test. COMTEN 95T was used as instrument. Tensile speed and temperature testing were conditioned at 3 mm/min and 25 °C, respectively. The specimen test was formed according to American Standard Testing Materials (ASTM) D882.

Thermal Stability

Thermal characteristic of PVA, bengkuang starch, and its blend film were tested using Mettler Toledo with TGA/DSC1 instrument. The thermal test was conducted at 30-500 °C. The heating rate was 10 °C/min under nitrogen conditions. The sampled weight was 7-10 mg.

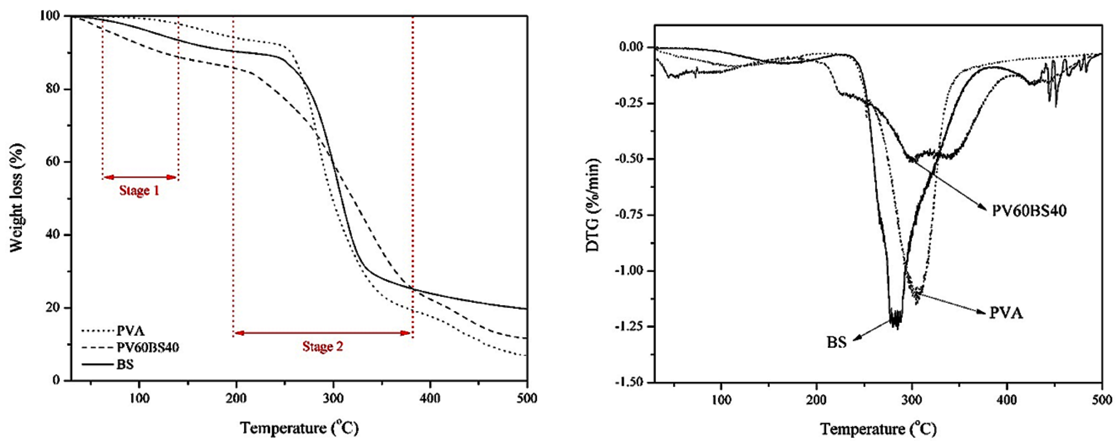
Moisture Absorption

All tested samples were 1 cm × 3 cm and dried in drying oven until constant weight. The initial and final weights are (W_o) and (W_t), respectively. The moisture absorption was carried out in moisture chamber (RH 99%) and 25 °C. The final weight (W_t) is the final weighing the sample every 30 min. The percentage of moisture absorption was calculated by equation below as reported by previous study.[3]

Moisture absorption= $[(W_t - W_0)/W_0] \times 100$ %

Functional Group Analysis

FTIR characterization was used to determine the functional groups of all samples. FTIR spectrum of



(a) (b)

Fig. 1: Thermal characteristic of sample tested (a) TGA (b) DTG

Table 1: Composition of PVA biocomposite mixture and Bengkuang Starch

No.	Sample Code	Glycerol (ml)	di-Natriumtetraborat-10-hydrat (g)	Composition (%) (from total weight of blend films = 5 g	
				PVA	Bengkuang starch
1.	PV100BS0	1	0.1	100	0
2.	PV80BS20	1	0.1	80	20
3.	PV60BS40	1	0.1	60	40
4.	PV40BS60	1	0.1	40	60
5.	PV20BS80	1	0.1	20	80
6.	PV0BS100	1	0.1	0	100

all samples tested was recorded by using Perkin-Elmer Frontier FTIR) instrument. The scanned wavenumber range in range 600 - 4000 cm^{-1} under 4 cm^{-1} resolution.

Statistical Analysis

The data from tensile strength were prepared and subjected to statistical analysis by using SPSS 25.0 (SPSS Inc., 160 Chicago, USA). They were analyzed using analysis of variance (ANOVA). Difference level was determined by Duncan Multiple Range Test (DMRT) at a confidence level of 95% ($p < 0.05$).

Results and Discussions

Tensile Properties

Tensile strength (TS) and tensile elongation (TE) were used to determine the mechanical characteristic of PVA, BS and its blend film. The TS and TE of all sample tested are presented on Table 2. The TS and TE value of PVA are 15.86 MPa and 225.64 %, respectively. This value is higher than BS and its blend films due to the high crystalline structure of PVA. The structure of PVA triggers a well intramolecular network formation between its chain and resulting in good mechanical properties.[10-12]

However, the addition of bengkuang starch into PVA decrease the TS and TE value. It is caused by bad

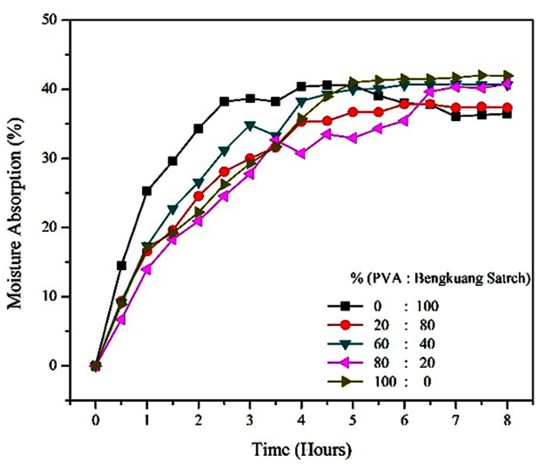


Fig. 2: Moisture absorption of all samples tested

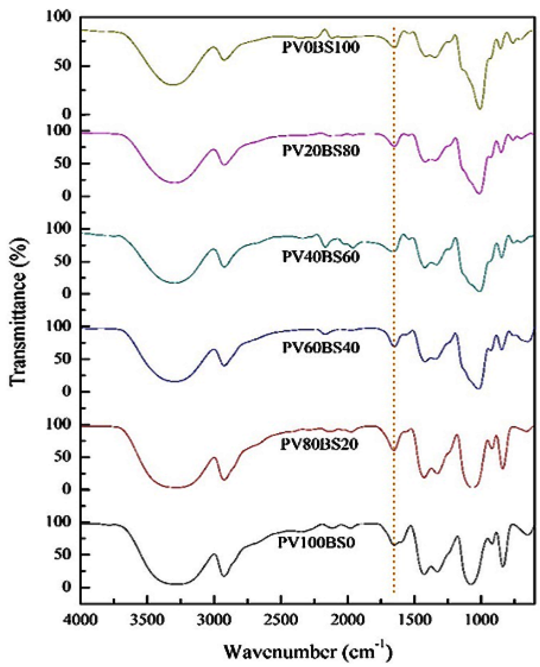


Fig. 3: FTIR spectrum of all samples tested

Table 2: Tensile strength and tensile elongation of blend films

No.	Sample code	Tensile Strength (MPa) *)	Tensile Elongation (%) *)
1.	PV100YS0	15.86 ± 0.69^a	225.64 ± 17.86^a
2.	PV80YS20	12.94 ± 0.19^b	165.42 ± 6.14^b
3.	PV60YS40	11.75 ± 0.19^c	142.29 ± 2.59^c
4.	PV40YS60	7.81 ± 0.23^d	113.16 ± 5.41^d
5.	PV20YS80	4.26 ± 0.16^e	60.50 ± 4.21^e
6.	PV0YS100	1.67 ± 0.27^f	30.88 ± 3.53^f

*) Different subscripts a, b, c, d, e, f in the same column indicate significant different at $p \leq 0.05$

interfacial bonding between PVA and bengkuang starch. Another reason, this phenomenon probably due to the presence of number free OH bonding between PVA and starch. Free OH affected in poor compatibility between PVA and bengkuang starch.[11] The starch has hydrophilic nature properties, so that the presence of starch to PVA matrix decrease the mechanical properties of blend films. Similar result was reported by previous researcher.[12]

Thermal Stability

Thermal characteristics of PVA, bengkuang starch, blend films are presented in the TGA dan DTG curve (Figure 1a and 1b). There are three degradation areas as reported by previous report.[13-14] First region is the initial degradation of all test samples in range temperature of 80-150 °C. This is indicated by increasing of weight loss percentage compared to the initial weight of sample before testing. The components lost in this area is water, glycerol, and urea.[6,15]

The second region (200-380 °C) is the major weight loss where all samples have a weight loss above 50%. It can be seen in Fig. 1a, pure PVA has a large percentage of weight loss (87%) and lower thermal stability than pure starch films. In this condition, the PVA structure has begun to break down.[6] This is supported by DTG curve which indicated small peak in this area. Meanwhile, the third region occurred above 380 °C, all samples are completely decomposed and generally have become carbon ash.[16-17]

Moisture Absorption

Figure 2 shows the percentage of moisture absorption of all sample tested. The pure PVA films have the highest moisture absorption compared to blend and pure starch films. The value of moisture absorption of pure PVA film at 8 h is 41.97 %. This is different with pure starch films which only have 36.50 % in these conditions. It is indicated that PVA is more hydrophilic than bengkuang starch.

This phenomenon is supported by FTIR data (Figure 3) in wavenumber 1653 cm^{-1}. PVA film has low transmittance (high absorbance). The similar result was also reported by previous study about PVA and pea starch.[12] The addition of bengkuang starch into PVA reduced moisture absorption of blend films. This is due to good interaction between starch and PVA molecules as reported by previous studies.[17-18]

Functional Groups Analysis

FTIR characterization was used to analyze functional groups of all sample tested. Figure 3 shows the FTIR spectrum for all samples. It can be seen that the peak appears in wavenumber 1653 cm^{-1} indicated carbonyl group.[19] It was corresponded by water absorption in all samples tested.

The pure PVA film has a lower transmittance compared to pure bengkuang starch film. The lowest transmittance indicated high absorbance. FTIR data is concordant with moisture absorption. The addition of bengkuang starch into PVA matrix resulting in higher transmittance. This indicates that the addition of starch reduced moisture absorption. This phenomenon is similar to that reported by previous report.[3,12]

Conclusions

Manufacturing of blend films from PVA and bengkuang starch has been successfully by solution casting method. The highest tensile strength was in pure PVA for 15.86 MPa. The addition of starch into PVA matrix decreases the tensile properties. PVA film has better thermal stability than bengkuang starch and its blend films. However, PVA is more hydrophilic than bengkuang starch. It is proved by moisture absorption test which PVA has high percentage of moisture. This is also supported by FTIR characterization which shows the presence of water absorption groups in wavenumber around 1653 cm^{-1}. This blend films probably suitable for food packaging application due to its potential properties.

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Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this manuscript. This manuscript has not been published and is not going to be considered for publication elsewhere. The authors certify that neither the manuscript nor its main contents have already been published or submitted for publication in another journal.

References

1. J.R. Jambeck, R. Geyer, C. Wilcox, T.R. Siegler, M. Perryman, A. Andrady, R. Narayan, K. L. Law, Plastic waste inputs from land into the ocean. *Science*. 347, 768-771 (2015).
2. W.C. Li, H.F. Tse, L. Fok, Plastic waste in the marine environment: A review of sources, occurrence and effects. *Sci. Total. Environ.* 566, 333-349 (2016).
3. M. Asrofi, H. Abral, A. Kasim, A. Pratoto, M. Mahardika, F. Hafizulhaq, Characterization of the sonicated yam bean starch bionanocomposites reinforced by nanocellulose water hyacinth fiber (WHF): The effect of various fiber loading. *J. Eng. Sci. Technol*. 13, 2700-2715 (2018).
4. C.G. Avio, S. Gorbi, F. Regoli, Plastics and microplastics in the oceans: from emerging pollutants to emerged threat. *Mar. Environ. Res*. 128, 2-11 (2017).
5. H. Abral, A. Hartono, F. Hafizulhaq, D. Handayani, E. Sugiarti, O. Pradipta, Characterization of PVA/cassava starch biocomposites fabricated with and without sonication using bacterial cellulose fiber loadings. *Carbohydr. Polym*. 206, 593-601 (2019).
6. N. Othman, N.A. Azahari, H. Ismail, Thermal properties of polyvinyl alcohol (PVOH)/corn starch blend film. *Malays. Polym. J.*, 6, 147-154 (2011).
7. X. Cao, Y. Chen, P.R. Chang, A.D. Muir, G. Falk, Starch-based nanocomposites reinforced with flax cellulose nanocrystals. *Express Polym. Lett*. 2, 502-510 (2008).
8. S. Mali, M.V.E. Grossmann, M.A. Garcıia, M.N. Martino, N.E. Zaritzky, Mechanical and thermal properties of yam starch films. *Food Hydrocoll*. 19, 157-164 (2005).
9. M. Asrofi, H. Abral, A. Kasim, A. Pratoto, M. Mahardika, F. Hafizulhaq, Mechanical properties of a water hyacinth nanofiber cellulose reinforced thermoplastic starch bionanocomposite: Effect of ultrasonic vibration during processing. *Fibers*. 6, 40 (2018).
10. M. Asrofi, H. Abral, Y.K. Putra, S.M. Sapuan, H.J. Kim, Effect of duration of sonication during gelatinization on properties of tapioca starch water hyacinth fiber biocomposite. *Int. J. Biol. Macromol*. 108, 167-176 (2018).
11. H. Abral, G.J. Putra, M. Asrofi, J.W. Park, H.J. Kim, Effect of vibration duration of high ultrasound applied to bio-composite while gelatinized on its properties. *Ultrason. Sonochem*. 40, 697-702 (2018).
12. Y. Chen, X. Cao, P.R. Chang, M.A. Huneault, Comparative study on the films of poly (vinyl alcohol)/pea starch nanocrystals and poly (vinyl alcohol)/native pea starch. *Carbohydr. Polym*. 73, 8-17 (2008).
13. M. Asrofi, H. Abral, A. Kasim, A. Pratoto, M. Mahardika, J.W. Park, H.J. Kim, Isolation of nanocellulose from water hyacinth fiber (WHF) produced via digester-sonication and its characterization. *Fiber. Polym*. 19, 1618-1625 (2018).
14. M. Mahardika, H. Abral, A. Kasim, S. Arief, M. Asrofi, Production of nanocellulose from pineapple leaf fibers via high-shear homogenization and ultrasonication. *Fibers*. 6, 28 (2018).
15. H. Abral, M.H. Dalimunthe, J. Hartono, R.P. Efendi, M. Asrofi, E. Sugiarti, S.M. Sapuan, J. W. Park, H.J. Kim, Characterization of tapioca starch biopolymer composites reinforced with micro scale water hyacinth fibers. *Starch-Starke.* 70, 1700287 (2018).
16. S. Wahono, A. Irwan, E. Syafri, M. Asrofi, Preparation and characterization of ramie cellulose nanofibers/$CaCO_3$ unsaturated polyester resin composites. ARPN *J. Eng. App. Sci*. 13, 746-51 (2018).
17. H. Abral, R.S. Satria, M. Mahardika, F. Hafizulhaq, J. Affi, M. Asrofi, D. Handayani, S.M. Sapuan, I. Stephane, E. Sugiarti, A.N. Muslimin, Comparative study of the physical and tensile properties of jicama (*Pachyrhizus erosus*) starch film prepared using three different methods. *Starch-Starke*. 1800224 (2019).
18. N.R. Savadekar, S.T. Mhaske, Synthesis of nano cellulose fibers and effect on thermoplastics starch based films. *Carbohydr. Polym*. 89, 146-151 (2012).
19. A. Mandal, D. Chakrabarty, Isolation of nanocellulose from waste sugarcane bagasse (SCB) and its characterization. *Carbohydr. Polym*. 86, 1291-1299 (2011).